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USE OF SELF-INDUCED HYPNOSIS TO MODIFY THERMAL BALANCE DURING COLD WATER IMMERSION.

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TECHNICAL REVIEW AND APPROVAL

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The experiments reported herein were conducted according to the principles set forth in the current edition of the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

This technical report has been reviewed by the NMRI scientific and public affairs staff and is approved for publication. It is releasable to the National Technical Information Service where it will be available to the general public, including foreign nations.

LARRY W. LAUGHLIN, CAPT, MC, USN

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>This study was designed to evaluate the efficacy of self-induced post-hypnotic suggestion to improve physical and thermogenic responses to two cycles of alternating rest and exercise during head-out immersion in 25 °C water. Twelve U.S. Navy divers volunteered to participate in two immersions conducted at the same time of day but spaced one week apart. The first immersion (control) was conducted prior to hypnotic training. The second immersion (hypnotic) was conducted following two 1-hour training sessions on mental imagery and post-hypnotic suggestion techniques. There were no differences in rates of heat production, heat loss or net thermal balance between control and hypnotic conditions for the grouped values. Hypnotic susceptibility, evaluated prior to the immersions, was not significantly correlated with the change in thermal balance or rectal temperature measurements evaluated between control and hypnotic immersions. Although the rating of perceived exertion during both exercise phases were similar for both immersions, subjects' perceived thermal sensation was reduced during the second rest

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phase of the hypnotic immersion when compared with the control immersion. Although the majority of subjects did not exhibit a hypnotic-induced alteration in thermoregulatory responses during immersion, 3 individuals seemed to respond to hypnosis, but in a manner that accentuated heat loss. These results suggest that the post-hypnotic training techniques employed in the present study did not enhance performance in divers during immersion in 25 °C. Whether a longer hypnotic training period or different training techniques would alter these results requires further research.

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INTRODUCTION

Immersion in cold water will eventually lead to a progressive reduction in core temperature as a consequence of the imbalance between heat production and heat loss mechanisms. Although heat production may be enhanced through muscular exercise, several studies have reported that cold water exercise accelerates core cooling (15,16,19,29) due to increased convective heat loss (26) and/or reduced peripheral insulation (36). It has also been suggested that a given workload and duration may be selected that balances heat loss during cold water immersion (13,22). For example, leg-only exercise of moderate intensity ($\dot{V}_{O_2}$ = 1.6 ℓ/min) was shown to maintain core temperature more effectively than rest in 18 °C water (35).

Non-exercise interventions can also raise heat production. Previous results from our lab have shown that caffeine ingestion leads to a greater increase in core temperature during exercise in 28 °C water than exercise alone (17). Another potential non-exercise mechanism for enhancement of metabolic heat production is self-induced hypnosis. For dry laboratory conditions, the suggestion of hard work has been shown to increase ventilatory minute volume (2,5,11) and oxygen consumption (11) while at rest, as well as alter ventilatory minute volume during exercise (18,24,25). Plasma free fatty acid levels and heart rate were significantly elevated following hypnotically simulated exercise (9). Hypnotic suggestion has also been shown to elicit the appropriate warm/cold thermogenic responses (32) and influence extremity blood flow (5). A combination of elevated metabolic heat production and reduced peripheral blood flow may lead to a more efficient thermoregulatory response during cold water stress.

In addition to the enhancement of physiological responses, hypnosis has been shown to alter psychological aspects of performance. For example, the relative perception of exertion during exercise has been shown to be reduced following post-hypnotic suggestion (1). In military personnel, hypnosis has been shown to improve performance of mental tasks, which include radar tracking and in-flight vigilance (3,4), as well as increase the steadiness while firing weapons (T. Mountz, personal communication). Whether U.S. Navy divers, who are commonly exposed to cold water stress during operational procedures, may enhance their performance through psychogenic mechanisms has not been investigated.

OBJECTIVES

The objective of the present study was to investigate the efficacy of self-induced hypnotic suggestion to improve mental, physical, and thermogenic responses during head-out immersion in 25 °C water. After a brief hypnotic training period, each subject underwent self-induced hypnosis in an effort to minimize his net loss of body heat during immersion. The water temperature was selected based on our previous laboratory studies that have shown that a thermally unprotected subject loses heat in 25 °C water at a similar rate as a diver wearing a dry suit in 5 °C water.

METHODS

1. SUBJECT CHARACTERIZATION

Twelve male U.S. Navy divers (age = 31.0 ± 4.1 yrs, height = 176.1 ± 7.3 cm, weight = 80.0 ± 7.3 kg, surface area = 1.96 ± 0.12 m^2, body fat = 17.6 ± 4.5%) volunteered to participate after giving their informed consent. Prior to undergoing immersions, subjects were evaluated by an independent psychologist for their hypnotic susceptibility using the Stanford Hypnotic Susceptibility Scale of 0 to 12, with 12 being most susceptible (37). Susceptibility scores for the subjects ranged from 2 to 12 with a mean value of 7 ± 3. An additional 3 subjects (age = 36.0 ± 7.3, height = 175.4 ± 9.4 cm, weight = 77.2 ± 7.5 kg, surface area = 1.93 ± 0.14 m^2) were evaluated to determine test/re-test reliability of the immersion measurements.

2. MEASUREMENTS

Seven calibrated heat flux transducers with imbedded thermistors (Thermonetics Corp., San Diego, CA) were placed on the subject to obtain weighted regional values of heat flux and skin temperature. Placement of sensors and weighting factors were those described by Hardy and DuBois (14). The 7 sites were the forehead, abdomen, thigh, calf, foot, forearm, and hand. A multiplexer was used to sequentially sample the 7 heat flux sites, providing a single input to an amplifier, and a corresponding output to a digital computer. Heat flux voltage was averaged for 5 sec at each site. A marker voltage was applied to the 8th channel of the multiplexer in order to delimit the 7 heat flux voltages in the computer buffer. This method of multiplexing required about 80 sec of real time. Therefore, the onset of heat flux sampling was begun every 2 min to coincide with the onset of oxygen consumption measurements.

Oxygen consumption ($\dot{V}_{O_2}$ L/min, STPD) and respiratory exchange ratio (RER) were measured each minute using an automated metabolic measurement cart (Beckman Instruments, Anaheim, CA). The minute values of $\dot{V}_{O_2}$ and RER that corresponded to the period of sampling of heat flux (i.e., every other minute) were entered manually into the computer for conversion to heat production according to the metabolic equivalent for oxygen (38):

$$kJ/min = \dot{V}_{O_2} \times [RER \times 5.156 + 15.971]$$

Total body heat loss was calculated from the sum of the 7 weighted heat flux measurements. No effort was made to calculate respiratory heat loss. Net thermal balance was calculated from the difference between heat production and heat loss. Regional and total heat flux, heat production, net thermal balance, and cumulative thermal balance were stored in a data file and also displayed on the computer monitor.

ECG electrodes were placed in a modified Lead II position to evaluate the heart rate response. The ECG complex was continuously monitored (Monitor 414, Tektronix, Inc., Beaverton, OR) and stored on a magnetic tape (Model 3968A, Hewlett Packard, Andover, MA) for off-line Fourier analysis of heart rate variability. Heart rates were manually recorded from the ECG monitor every 5 min.

A YSI-401 thermistor was inserted 15 cm beyond the anal sphincter for measurement of rectal temperature (Tre). Tre and skin temperatures were recorded manually every 5 min. Mean skin temperature (Tsk) was calculated from the sum of the 7 weighted skin temperatures.

3. IMMERSION PROTOCOL

During each immersion trial the subject remained at rest until his net heat loss approximated 200 kJ (Rest Phase I). He then performed leg exercise (Exercise Phase I) in a semi-recumbent position at a workload of 50 W ($\dot{V}_{O_2} \cong$ 1.5 ℓ/min) until net thermal balance returned to zero (gain = 200 kJ). The subject rested a second period (Rest Phase 2) until net thermal balance declined approximately 100 kJ, followed by a second 50 W exercise period until this cumulative heat loss was replaced (Exercise Phase 2). The time to lose or gain the designated heat in each phase was measured to the nearest whole minute.

Two days prior to their initial control immersion, subjects performed a submaximal graded exercise test on a cycle ergometer (W.E. Collins, Inc., Braintree, MA) modified for underwater exercise. This preliminary exercise was conducted to familiarize the subjects with the experimental water temperature and cycle ergometer exercise. Each subject participated in two test immersions spaced 1 week apart and conducted at the same time of day. The initial immersion (CONTROL) for all subjects was done in the absence of any hypnotic training or post-hypnotic suggestion. Thus, each subject served as his own control. The second immersion test (HYPNOSIS) was done after each subject had received two 1-hour sessions on self-hypnosis, administered by a trained hypnotist (see details below). The HYPNOSIS immersion was conducted within 2 days of completing the hypnosis training. The CONTROL trial was always done first in an attempt to eliminate any tendency for the subject to invoke the post-hypnotic suggestion on his CONTROL immersion.

The subject refrained from alcohol and caffeine consumption 24 hours before the trials and ate a light breakfast about 3 hours before immersion. Ninety minutes prior to beginning each immersion, the subject reported to the lab where all experimental procedures were conducted. After being weighed, the subject consumed a volume of deionized water equal to 0.5% of body weight to ensure adequate hydration. Following placement of measurement devices, the subject donned a lightweight running suit (80% nylon, 20% lycra), which kept transducers in place throughout the immersion. The insulative value of the garment was minimal, as determined from calibration of transducers with and without the suit material (differences ranged from 1-4.9%; mean difference = 2.5%). For the next 30 min the subject either quietly rested (CONTROL) or performed self-hypnosis (HYPNOSIS).

After the initial quiet period, the subject was seated beside the immersion tank and baseline data were collected for 10 min. The subject was then assisted into the immersion tank and secured himself in the seat of the cycle ergometer. Data collection was initiated after 1 min elapsed from the time the subject initially entered the tank. The water was continuously stirred and maintained at 25.0 ± 0.1 °C, with the level set just below the subject's chin. At minute 10 of each rest phase the subject was asked to rate his perceived thermal sensation (PTS) from a 0-10 scale reported by Gagge et al. (12) where 0 is very cold and 10 is very hot. Immediately following each exercise phase, the subject was asked to rate his relative perceived effort (RPE) according to the scale developed by Borg (7) where 0 is very easy and 10 very difficult.

After completion of the second exercise phase, the subject was removed from the tank. A questionnaire designed to assess the subject's evaluation of his hypnotic state and methods used to induce hypnosis was then administered.

4. HYPNOTIC TRAINING SESSIONS

Similar hypnosis induction techniques and post-hypnotic instructions were employed with all subjects. These were based upon the traditional methods of gradual suggestions for fixed concentration, upward eye-gaze, progressive relaxation, numerical countdown, and eyelid closure. Clinical judgment was used to assess appropriate level of induction. After approximately 15-20 min of induction, the subject was considered to be sufficiently hypnotized. Suggestions were then provided to allow the subject to visualize, via appropriate mental imagery, the experimental situation, with special reference to immersion. The general image was to be one where the subject visualized performing continuous exercise while immersed and that the exercise would be effortless and non-fatiguing. This image was chosen in the hope of elevating heat production at rest, and yet minimize heat loss since the image included immersion. These suggestions were strongly reinforced. Future-tense post-hypnotic instructions were also provided suggesting the subject could work without fatigue during exercise in the immersion tank. Direct suggestions of thermal sensations or physiological changes were avoided.

Following these imagery-based procedures, the subject was then gradually alerted by a traditional count-up method.

5. DATA ANALYSIS

Differences in measurements between the CONTROL and HYPNOSIS immersions for both phases of rest and exercise were determined by a 2 x 2 analysis of variance (ANOVA) for repeated measures. Dry rest phase values were compared by paired Student's t-tests. Correlation coefficients were calculated to determine the relationship between hypnotic susceptibility and the changes observed between CONTROL and HYPNOSIS immersions. Statistical significance was set at the 0.05 level. One subject was unable to complete his entire HYPNOSIS trial due to a reduced T_{re}, thus means ± standard errors of the means (SEM) for the data for 11 subjects are reported.

RESULTS

Group values for rates of net thermal balance, heat production, and heat loss are reported in Table 1. There were no significant differences observed between CONTROL vs. HYPNOSIS conditions for any variable.

During the initial rest phase, cumulative net thermal balance reached -202.73 ± 2.68 kJ in 22 ± 3 min and -203.51 ± 1.99 kJ in 19 ± 2 min for the CONTROL and HYPNOSIS immersions, respectively. Exercise at 50 W increased heat production approximately three-fold (Table 1), which resulted in a net gain in thermal balance of 208.13 ± 3.87 kJ during the CONTROL immersion and 206.69 ± 5.00 kJ during HYPNOSIS. The respective exercise times were 15 ± 1 and 14 ± 1 min for CONTROL and HYPNOSIS. Net thermal balance was subsequently reduced in the second rest phase to -101.03 ± 7.93 kJ for CONTROL and -105.82 ± 4.86 kJ for HYPNOSIS. The respective times to lose this amount of heat were 29 ± 4 and 20 ± 2 min. The final 50 W exercise phase resulted in the replacement of 117.28 ± 5.09 and 109.92 ± 3.17 kJ of net heat for CONTROL and

HYPNOSIS immersions, respectively. Exercise time for both immersions was identical (8 ± 1 min). Although the times to lose heat during both rest phases were reduced in the HYPNOSIS trial, these differences were not statistically significant ($F = 3.18$, $p = .10$).

Rates of heat loss and production at rest were significantly lower in phase 2 than phase 1 for both conditions (see Table 1), with the magnitude of the decrease greater for heat loss. Thus, the rate of net heat loss during the second rest phase was less than phase 1 ($F = 32.29$, $p < 0.01$). In contrast, the rate of net heat gain was similar for the exercise phases in both conditions due to similarities in heat loss and production ($F = 0.07$, $p > 0.79$). The rate of net heat gain observed for the CONTROL immersion during the second exercise phase was slightly higher than in phase 1. On the other hand, during the HYPNOSIS trial there was a slight decrease in net heat gain in the second exercise phase compared to the first exercise phase. These slight changes resulted in the detection of a significant interaction between CONTROL and HYPNOSIS conditions during the second exercise phase ($F = 11.06$, $p < 0.01$).

Measurements of Tre and Tsk during all phases for both immersions are reported in Table 2. Two subjects did not have complete data for Tre, thus 9 subjects were included in the statistical comparisons. No differences were observed between CONTROL and HYPNOSIS immersions for either temperature measurement. The decrease in Tre during immersion was minimal for both conditions (-0.3 ± 0.2 vs. -0.2 ± 0.1 °C for CONTROL and HYPNOSIS, respectively). Tsk was significantly reduced in phase 2 of both rest and exercise compared to phase 1 ($F = 77.35$, $p < 0.01$). Heart rate responses during rest and exercise phases were also similar between immersions (Table 2).

A slight, but significant reduction in exercise heart rate ($F = 7.89$, $p < 0.05$) was observed for the second phase in both CONTROL and HYPNOSIS immersions.

The self-induced hypnotic suggestion did not alter the subjects' ratings of perceived exertion (RPE) during both exercise phases (EX1 = 1.8 ± 0.3 vs. 2.0 ± 0.3, EX2 = 2.0 ± 0.3 vs. 1.9 ± 0.3, for CONTROL and HYPNOSIS, respectively). Perceived thermal sensation (PTS) was similar during the first rest period (CONTROL = 2.9 ± 0.2, HYPNOSIS = 3.0 ± 0.2). However, subjects felt warmer during the second rest phase of the HYPNOSIS trial (PTS R1 = 3.3 ± 0.2, R2 = 2.6 ± 0.2, $p < 0.05$). In support of this difference in PTS, 7 out of 10 subjects stated on the post-immersion questionnaire that they subjectively felt better and more relaxed during the HYPNOSIS immersion.

Correlation coefficients were determined for the relationship between pre-experiment hypnotic susceptibility scores and changes in thermal variables. Hypnotic susceptibility was not significantly correlated with the absolute change in rates of net thermal loss or gain during each phase (Figure 1). No significant correlations existed for changes in heat loss, heat production, and rectal temperature responses versus susceptibility score.

Individual differences were observed in the response to hypnosis. One subject with a high susceptibility score of 12, showed an enhanced rate of heat loss (Figure 2) that resulted in a faster time to lose the required heat (Figure 3). During the administration of the post-immersion questionnaire this subject stated he utilized "relaxation and deep breathing" procedures to induce his "hypnotic" state. Another subject, who altered his thermal balance during his HYPNOSIS immersion, imagined himself "cycling on a warm day." As a result, his rate of net heat loss during the first rest phase increased by 3.5 kJ/min and by 4.13 kJ/min during the second rest phase over CONTROL values. The susceptibility score for this subject was 2.

The mean values for the 3 control subjects during test-retest immersions are reported in Table 3. Although only 3 subjects were evaluated, the percent change from first to second immersed test was generally less than 10%.

DISCUSSION

In the present study, self-induced hypnosis was utilized in an attempt to alter thermal balance during immersion in 25 °C water. The results were equivocal. As a group, the short hypnotic training period did not consistently improve thermal status during immersion. Aside from individual variability, there were certain individuals who appeared to modify their response to cool water through self-induced hypnosis.

Previous studies have reported that hypnosis alters several variables that may contribute to control of thermal balance. These include skin resistance (20,32), skin and oral temperature (21,30,33), and vasomotor responses (8,31). However, peripheral circulation and skin temperature have also been found to be unaltered by hypnosis (6,28). Peters and Stern (27) reported an increase in skin temperature and pulse volume throughout the hypnosis period, although a similar increase was observed during a control relaxation period. Thus the authors concluded that relaxation rather than hypnosis per se accounted for these changes.

Kissen et al. (20) observed an increase in the rate of heat loss in 5 males during hypnosis when compared with a nonhypnotic resting exposure to 4 °C air for 60 min. These authors reported a reduced shivering response during the hypnotic cold exposure and suggested that hypnosis can modify the normal thermoregulatory response pattern. One subject in our study who concentrated on relaxation during his hypnotic immersion also had an enhanced rate of heat loss, thus the question arises as to whether hypnosis or relaxation per se contributed to the alterations observed by Kissen et al. (20).

The use of hypnotic suggestion and imagery of exercise while at rest has been shown to elevate heart rate (2,9), ventilatory minute volume (2,5,11), and oxygen consumption (11). The latter variable may lead to an enhanced heat production. Although hypnosis employed during physical exercise has resulted in alterations in minute ventilation, little or no change in oxygen consumption has been observed (18,24,25). Our results revealed no differences in oxygen consumption or minute ventilation during either the rest or work phases of the immersion.

Jackson et al. (18) found that subjects with a high hypnotic susceptibility had significantly different ventilatory responses to maximum exercise when compared with controls or subjects in a low susceptibility group. The hypnotic susceptibility scores of the present subjects, determined by a standard rating scale (37), did not correlate with hypnosis-induced changes in variables comprising thermal balance. This finding was similar to Crosson (10) who observed a lack of correlation between hypnotic susceptibility and temperature regulation during hypnosis.

The lack of hypnotic effect on rating of perceived exertion during the exercise phase was not unexpected in the present study in light of the similar ventilatory responses. Morgan et al. (24,25) suggested that alterations in perceived exertion induced by hypnosis were associated primarily with hyperventilation. The fact that the ratings of perceived exertion were not altered during the second phase of the hypnotic immersion may also reflect the light workload employed. Seventy-eight percent of the RPE responses during both phases and both conditions fell between 2 and 3 on the 10-point scale.

Hypnosis did result in an enhanced perception of greater warmth, but only during the second rest phase. Kissen et al. (20) also noted that hypnosis was capable of reducing the sensation of cold. Since thermal sensation was significantly altered by hypnosis only during the second rest phase, it is plausible that the initial period of cool water immersion stimulates cold sensations to an extent that cannot be overridden by hypnotic interventions. After the initial cold exposure, peripheral adaptation may occur that permits potentiation of hypnotic suggestions.

Although the majority of subjects did not exhibit hypnotic-induced alteration in thermoregulatory responses, 3 individuals seemed to respond to hypnosis in a manner that was opposite from what we had hoped to achieve. They lost heat at a faster rate. These subjects reportedly used relaxation techniques or mental imagery of "cycling on warm days." The relaxation might suppress shivering, thereby reducing heat production. The image of a warm day may evoke vasodilation to enhance rate of heat loss. It is possible that the lack of overall improvement in thermal balance observed in the present group may be attributed to combinations of insufficient hypnotic training or use of inappropriate imagery.

We attempted to evoke an image of effortless cycling during cool water immersion, in hopes of raising heat production and minimizing heat loss. The fact that the aforementioned subjects imagined only "relaxation" or included "warm day" suggests inadequate training rather than a complete absence of a hypnotic effect.

Although the subjects stated they employed the imagery and suggestion techniques learned from the hypnotist, these techniques alone may not be effective in inducing physiological changes. Crosson (10) compared subjects' ability to control skin temperature during hypnosis using biofeedback, suggestion and imagery, and a combination of biofeedback and suggestion and imagery. He concluded that biofeedback, not suggestion and imagery, was effective for creating temperature change. Whether the present protocol would have benefitted by an increased number of hypnotic training sessions or the use of biofeedback needs to be investigated. The fact that some individuals appeared to respond to hypnosis would suggest that it can work during immersion, but additional studies would be required to define how this can best be done.

An additional factor contributing to the equivocal results found in the present study is the variability observed between the test-retest immersions. For the hypnotic effect to be physiologically significant, an alteration in thermal responses should have been greater than 10%. Therefore, a small improvement in thermal balance due to hypnosis may have been masked by the test-retest variability.

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TABLE 1

Mean values (± SEM) for rates of net heat loss/gain, heat production and heat loss (n = 11).

CONDITION	NET LOSS/GAIN (kJ/min)	HEAT PRODUCTION (kJ/min)	HEAT LOSS (kJ/min)
PRE-IMMERSION			
CONTROL	-0.94 ± 0.31	6.16 ± 0.34	7.06 ± 0.33
HYPNOSIS	-0.76 ± 0.29	6.00 ± 0.21	6.76 ± 0.28
REST PHASE 1			
CONTROL	-10.45 ± 1.15	10.14 ± 0.41	20.45 ± 1.18
HYPNOSIS	-11.90 ± 1.16	10.01 ± 0.47	21.68 ± 1.12
EXERCISE PHASE 1			
CONTROL	14.80 ± 0.99	29.08 ± 0.65	14.95 ± 0.79
HYPNOSIS	14.84 ± 0.77	29.41 ± 0.64	15.27 ± 0.55
REST PHASE 2			
CONTROL	-4.72 ± 0.58*	9.55 ± 0.46*	13.65 ± 0.59*
HYPNOSIS	-5.87 ± 0.48*	8.14 ± 0.48*	14.18 ± 0.40*
EXERCISE PHASE 2			
CONTROL	15.79 ± 0.84	28.53 ± 0.57	13.14 ± 0.69
HYPNOSIS	13.53 ± 0.49	27.14 ± 0.60	13.60 ± 0.41

* Significantly different from phase 1

TABLE 2

Mean values (± SEM) for rectal temperature (n = 9), mean skin temperature, ventilation (n = 11), and heart rates (n = 10).

CONDITION	Tre (°C)	Tsk (°C)	$\dot{V}_E$ (L/min, BTPS)	HR (bpm)
PRE-IMMERSION				
CONTROL	37.0 ± 0.1	31.8 ± 0.3	10.3 ± 0.9	64 ± 3
HYPNOSIS	36.9 ± 0.1	32.2 ± 0.2	10.4 ± 0.9	64 ± 2
REST PHASE 1				
CONTROL	36.9 ± 0.1	27.0 ± 0.1	13.5 ± 0.9	61 ± 3
HYPNOSIS	36.9 ± 0.1	27.0 ± 0.1	14.0 ± 1.0	59 ± 3
EXERCISE PHASE 1				
CONTROL	36.8 ± 0.1	26.6 ± 0.1	34.3 ± 1.0	105 ± 2
HYPNOSIS	36.8 ± 0.1	26.7 ± 0.1	35.7 ± 1.3	105 ± 2
REST PHASE 2				
CONTROL	36.7 ± 0.2	26.7 ± 0.1*	14.5 ± 1.0	62 ± 2
HYPNOSIS	36.8 ± 0.2	26.8 ± 0.1*	13.4 ± 0.7	60 ± 2
EXERCISE PHASE 2				
CONTROL	36.6 ± 0.2	26.4 ± 0.1*	35.0 ± 0.7	102 ± 3*
HYPNOSIS	36.7 ± 0.1	26.5 ± 0.1*	34.9 ± 1.6	104 ± 2*

Values for Tre and Tsk were determined from final measurement obtained during each phase. $\dot{V}_E$ = ventilatory minute volume; HR = heart rate. $\dot{V}_E$ and HR were averaged over entire phase.

* Significantly different from phase 1.

TABLE 3

Mean values for first (T1) immersion and percent change observed during second (T2) immersion for 3 control subjects.

VARIABLE		PHASE				
		Dry Rest	Rest 1	Exercise 1	Rest 2	Exercise 2
Net loss/gain (kJ/min)	Mean	-2.45	-13.30	11.88	-7.45	13.42
	SE	1.54	1.63	1.62	1.75	0.89
	%diff	56.7	14.2	7.6	12.3	8.0
Heat production (kJ/min)	Mean	4.99	9.81	28.79	9.01	28.58
	SE	0.27	0.73	1.46	0.63	1.59
	%diff	14.5	7.2	3.2	11.0	3.7
Heat loss (kJ/min)	Mean	7.44	22.92	16.99	15.25	14.77
	SE	1.35	2.21	2.13	1.11	1.62
	%diff	7.4	6.9	5.4	7.8	5.0
Tre (°C)	Mean	37.0	36.9	36.8	36.9	36.9
	SE	0.1	0.1	0.2	0.2	0.2
	%diff	0.2	0.6	0.8	0.6	0.3
Mean Tsk (°C)	Mean	32.1	27.1	26.8	27.0	26.5
	SE	0.5	0.2	0.1	0.2	0.1
	%diff	1.3	0.5	0.5	0.7	0.7
Heart rate (bpm)	Mean	74	71	114	79	114
	SE	12	10	10	9	10
	%diff	5.9	8.6	2.8	5.0	3.5
Ventilation (L/min, BTPS)	Mean	7.2	13.0	37.2	12.9	35.0
	SE	0.6	1.2	5.2	1.5	4.3
	%diff	16.2	10.7	7.3	6.2	10.7

%diff = (T1 - T2)/T1 * 100

LAY LANGUAGE SUMMARY

Psychological alterations of one's mental state have been shown to result in significant changes in mental and physical performance. Use of self-induced hypnosis, or other forms of mental imagery, can improve attention or enhance certain aspects of athletic endeavors.

The present study examined the efficacy of self-induced hypnosis to improve net thermal status during rest and exercise while immersed in 25 °C (77 °F) water. Twelve U.S. Navy divers volunteered to participate in the study. Prior to the immersion tests, each subject completed a standard questionnaire to assess his hypnotic susceptibility, with the results of the questionnaire made known only after the study was completed.

The first immersion test for all subjects was a control immersion done without any hypnotic training. Subjects wore heat flux sensors and a rectal thermistor to measure body heat loss. Body heat production was calculated from oxygen consumption. Net thermal balance was the difference between heat production and loss. The subjects remained at rest until their net thermal balance had declined by a fixed amount (200 kilojoules). They then exercised at a light workload until they had regained this amount of heat. A second rest period then followed where they remained at rest until they had lost half as much heat as the first period (e.g., 100 kilojoules) and then exercised a second time until the heat loss was regained.

The week following the first test subjects received two one-hour training sessions in self-induced hypnosis. Within two days after the training sessions the subjects underwent a second immersion test, using the same net thermal balance criteria as the first immersion. The times to lose or regain these fixed amounts of heat were compared between the control and hypnotic tests to ascertain any changes that might be induced by hypnosis. Preliminary testing had shown that ·uch changes would have to be about 10% or greater to be meaningful.

As a group, there were no significant differences between control and hypnotic tests for rates of heat loss or heat production. There were no differences in perceived exertion during the exercise periods with either control or hypnosis testing. During the hypnosis immersion, subjects reported feeling significantly warmer during the second rest period. There were no correlations between individual subject scores on the pre-test hypnotic susceptibility questionnaire and measures of thermal balance.

Although as a group no significant effects of self-induced hypnosis could be demonstrated, individual responses indicated that this form of mental imagery may, in fact, be able to alter thermogenic responses in cold water. Three subjects lost heat at a faster rate during their hypnosis immersion than during the control immersion. A questionnaire completed after each immersion revealed that 2 of these subjects had concentrated on relaxation. Consequently, they appeared to shiver less and lost heat faster than during their control runs. Although they lost heat faster, these subjects also stated they felt much warmer in the cold water. The third subject who lost heat faster during hypnosis employed an image of cycling on a warm day, and thus may have evoked heat loss mechanisms rather than heat conservation measures.

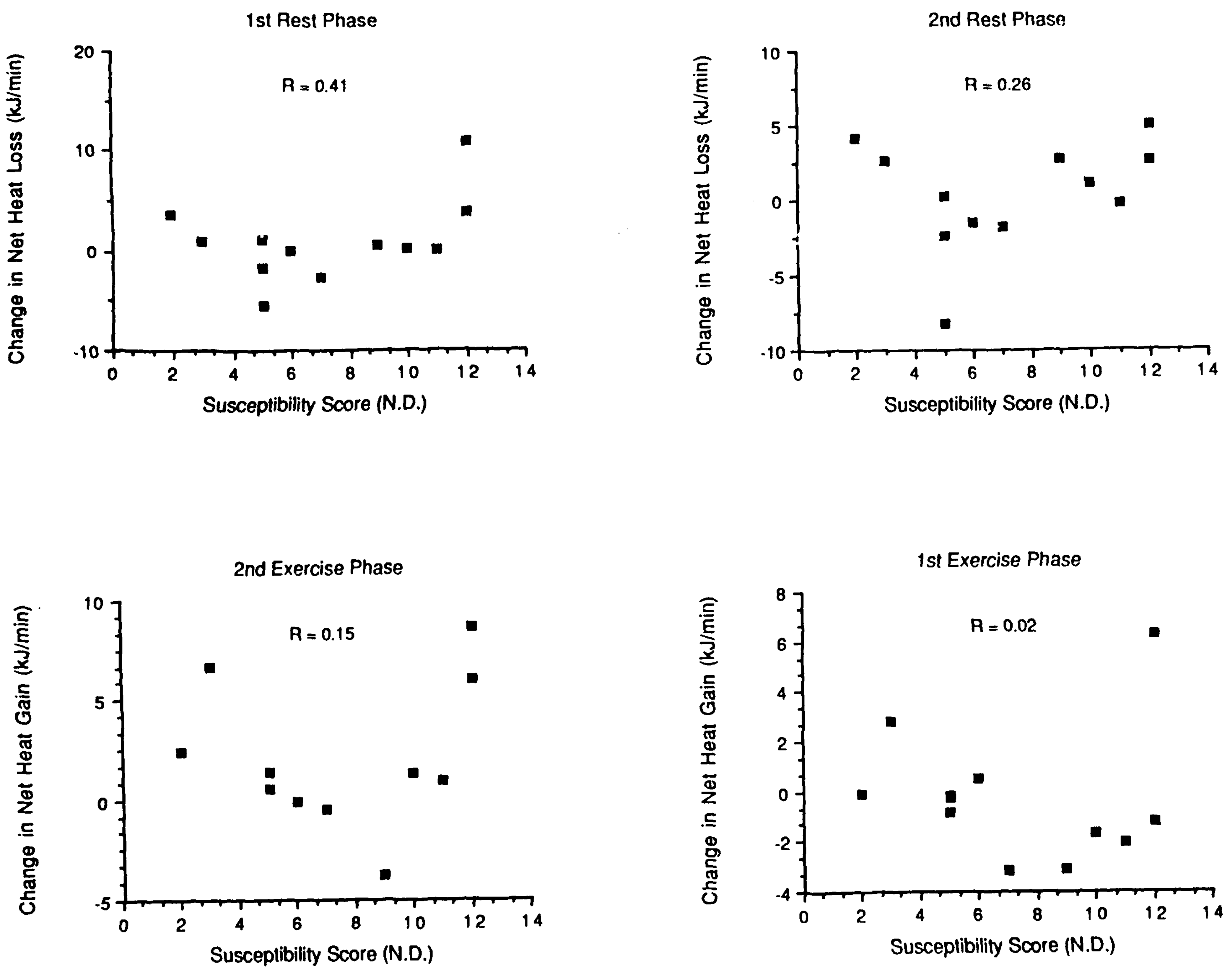
The results of this study indicate that a short training session in self-induced hypnosis will not produce a noticeable change in thermal balance when immersed in cold water. Standard questionnaires of hypnotic susceptibility do not result in scores that correlate with alterations in thermal status. Individual subjects who did exhibit notable changes in thermal balance with use of hypnosis employed mental images that produced physiological changes opposite to that which would be needed to improve tolerance to cold water. It is possible that an increase in the amount of training, coupled with other forms of mental imagery, may result in enhanced thermal responses to cold water. The preliminary results of the present study warrant further consideration with the above possibilities in mind.

FIGURE LEGENDS

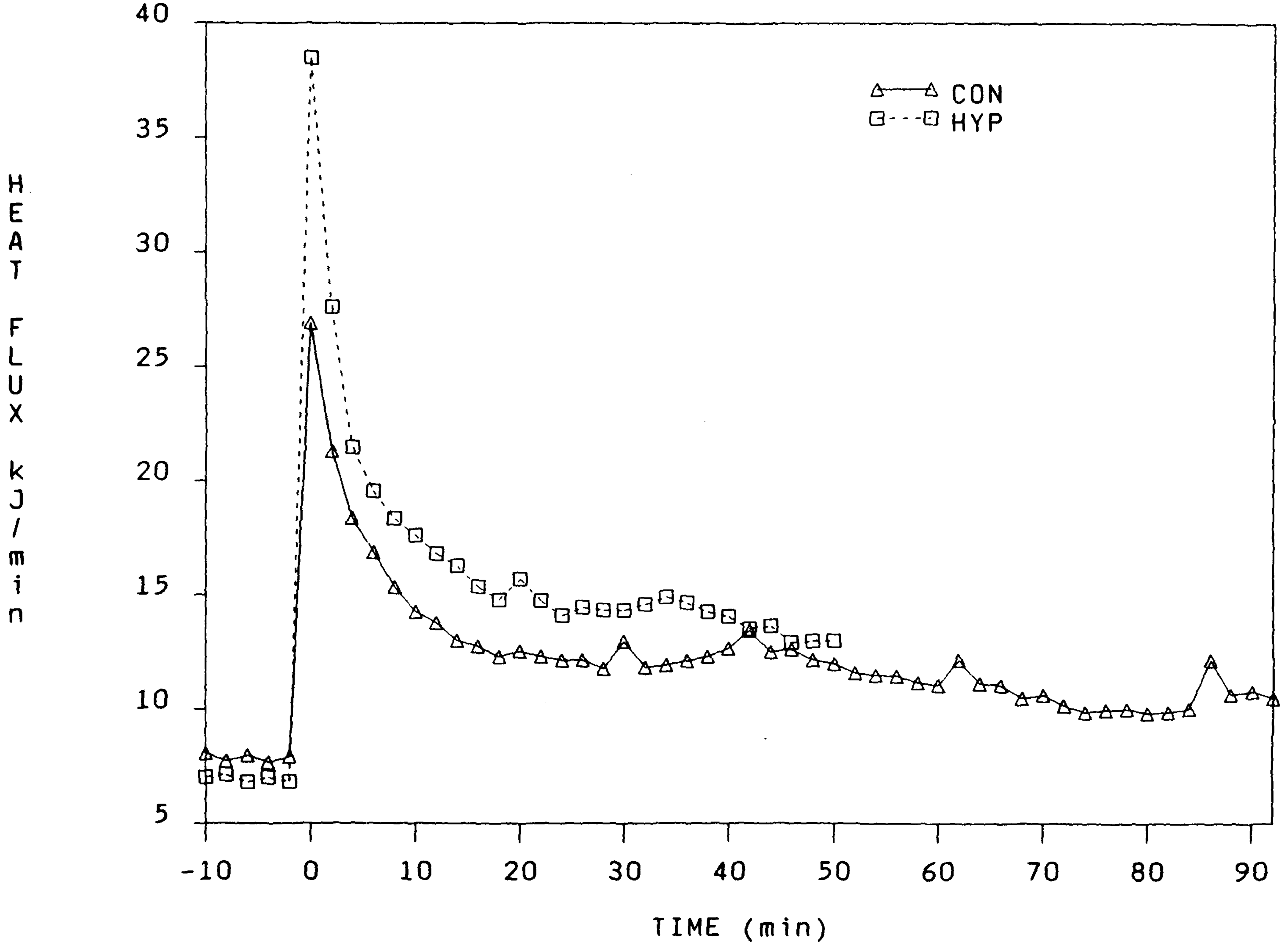
Figure 1: Correlation of Stanford Hypnotic Susceptibility Scores with indices of thermal balance. Value of score has no dimension (N.D.)

Figure 2: Rate of heat loss in subject #6 for CONTROL (CON) and HYPNOSIS (HYP) immersions.

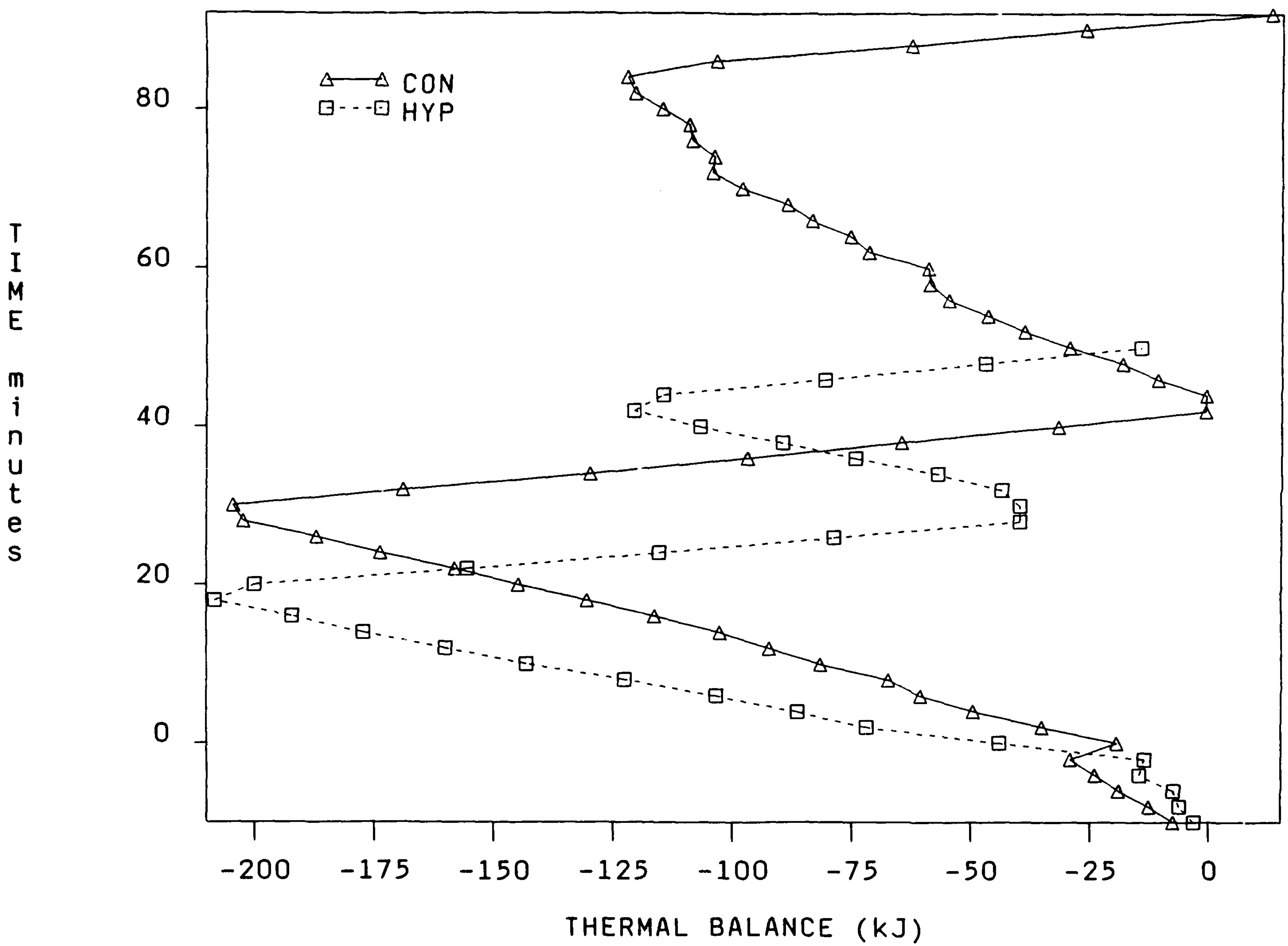
Figure 3: Time to lose or regain net thermal balance in subject #6 during CONTROL (CON) and HYPNOSIS (HYP) immersions.



1st Rest Phase
R = 0.41
Change in Net Heat Loss (kJ/min)
Susceptibility Score (N.D.)
2nd Rest Phase
R = 0.26
Change in Net Heat Loss (kJ/min)
Susceptibility Score (N.D.)
2nd Exercise Phase
R = 0.15
Change in Net Heat Gain (kJ/min)
Susceptibility Score (N.D.)
1st Exercise Phase
R = 0.02
Change in Net Heat Gain (kJ/min)
Susceptibility Score (N.D.)



CON
HYP
HEAT FLUX kJ/min
TIME (min)
40
35
30
25
20
15
10
5
-10
0
10
20
30
40
50
60
70
80
90


CON
HYP
TIME minutes
80
60
40
20
0
-200
-175
-150
-125
-100
-75
-50
-25
0
THERMAL BALANCE (kJ)